



# Mobility, wireless, ad hoc...

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# Networking at “The Edge”

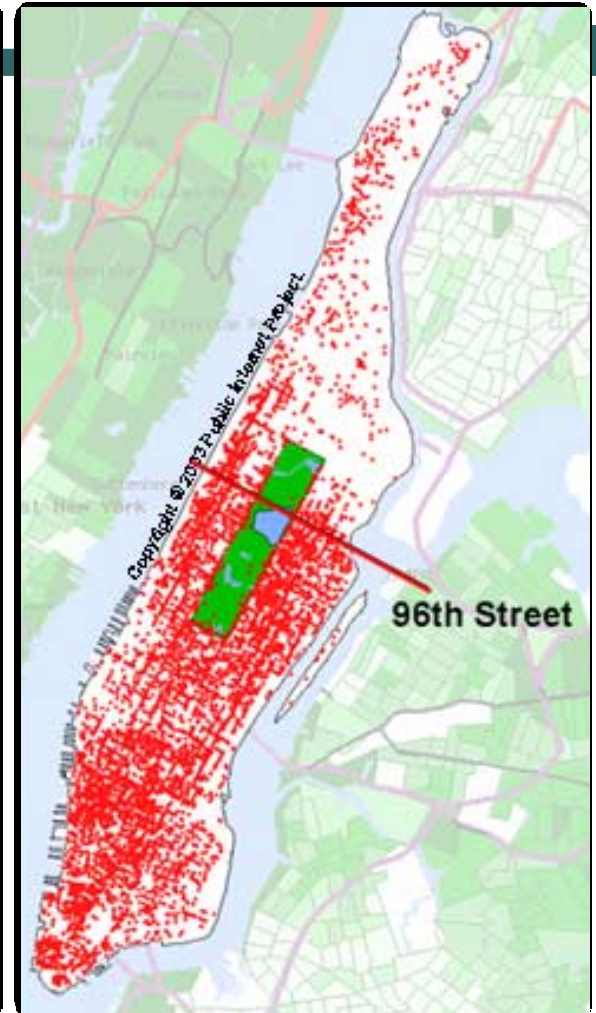
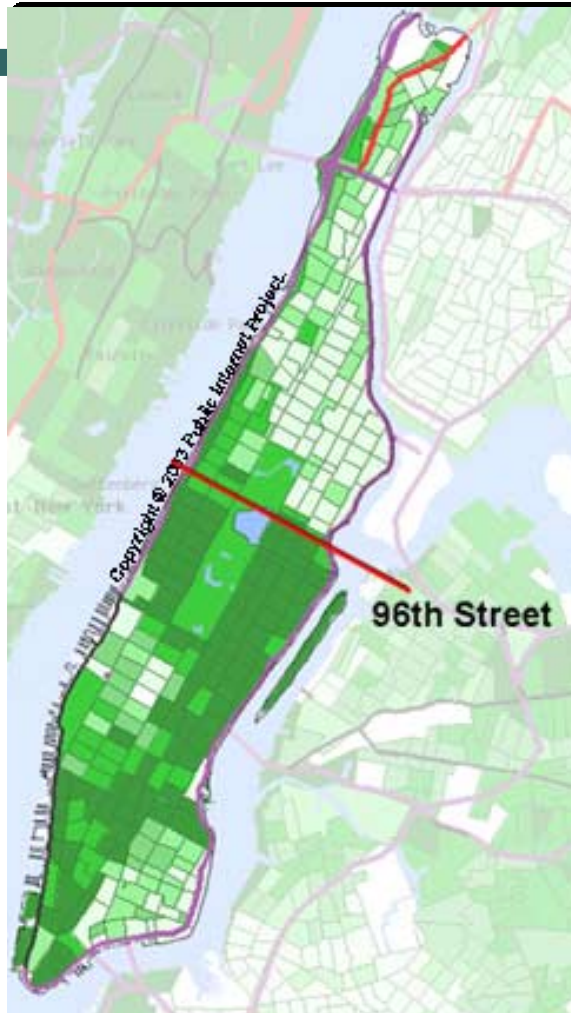
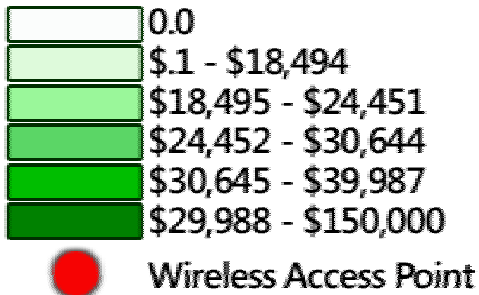


# Broadband map

Source: <http://publicinternetproject.org>

- 13,707 unique nodes within Manhattan (Fall 2002)
- 91% below 96th Street

## Median Family Income 1990



Emerging technologies may fill this gap

# Where We Want to Go ?

- **Network Everywhere**

***A vision where every person and every device is connected to the network and is the ultimate realization of Metcalf's Law***

**Mimic social networks today, rather than technical bounds**

**Technology molds to fit policy and interaction, rather than people molding to fit technical bounds**

**The value of the network is directly proportional to the connectivity of the network**

- **How do we get there?**

# Issues to address

- **Ubiquitous, low cost, open infrastructure**

**For communication with low-cost computing devices (sensors, controllers...)**

**Devices to determine its location and potentially use spatial information for routing and infrastructure setup**

**Coherent and integrated framework for security with robust operation in face of any sort of attack**

**To address needs/requirements in times of crisis**

**Quantum computers? Security to protect privacy of data also in case quantum computer are available**

**Mechanism for configuration and diagnosis Internet nodes to reduce manual intervention and provide application-network behaviour**

**Consider energy and highly efficient usage of spectrum**

# Self Forming Service Networks

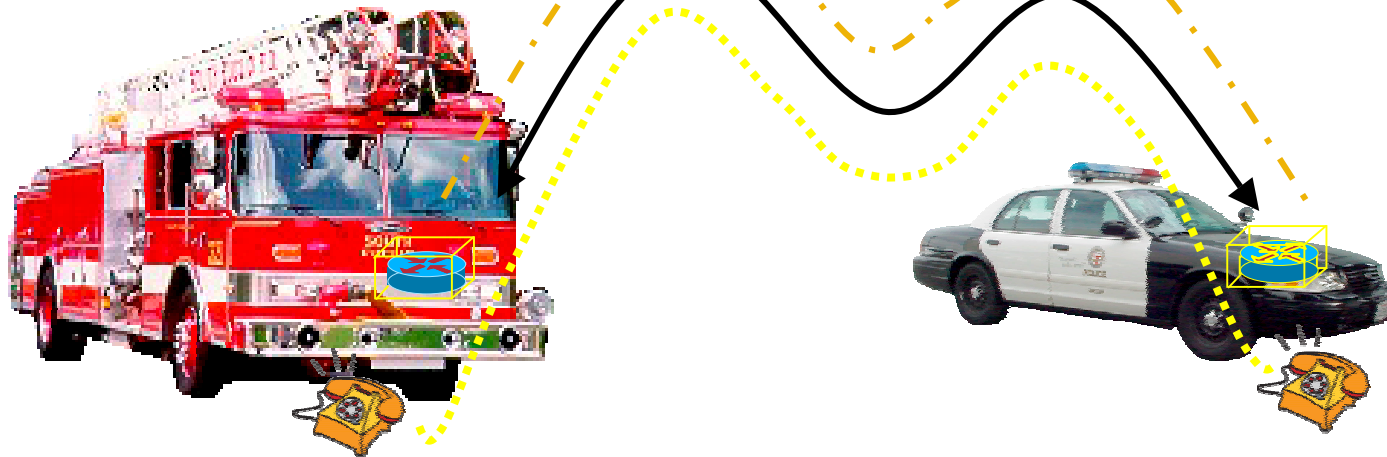
- **Objective: service delivery without prior arrangement**
- **What does service delivery mean?**

**If two entities can establish link layer communications then those entities should be able to communicate utilizing a specific set of services**

# High level requirements

If a single fire fighter and police officer arrive on the scene of an accident and both carry a radio they can achieve link layer communications

Given that they can achieve physical/link layer connectivity then they should be able to establish a border and peer between their domains

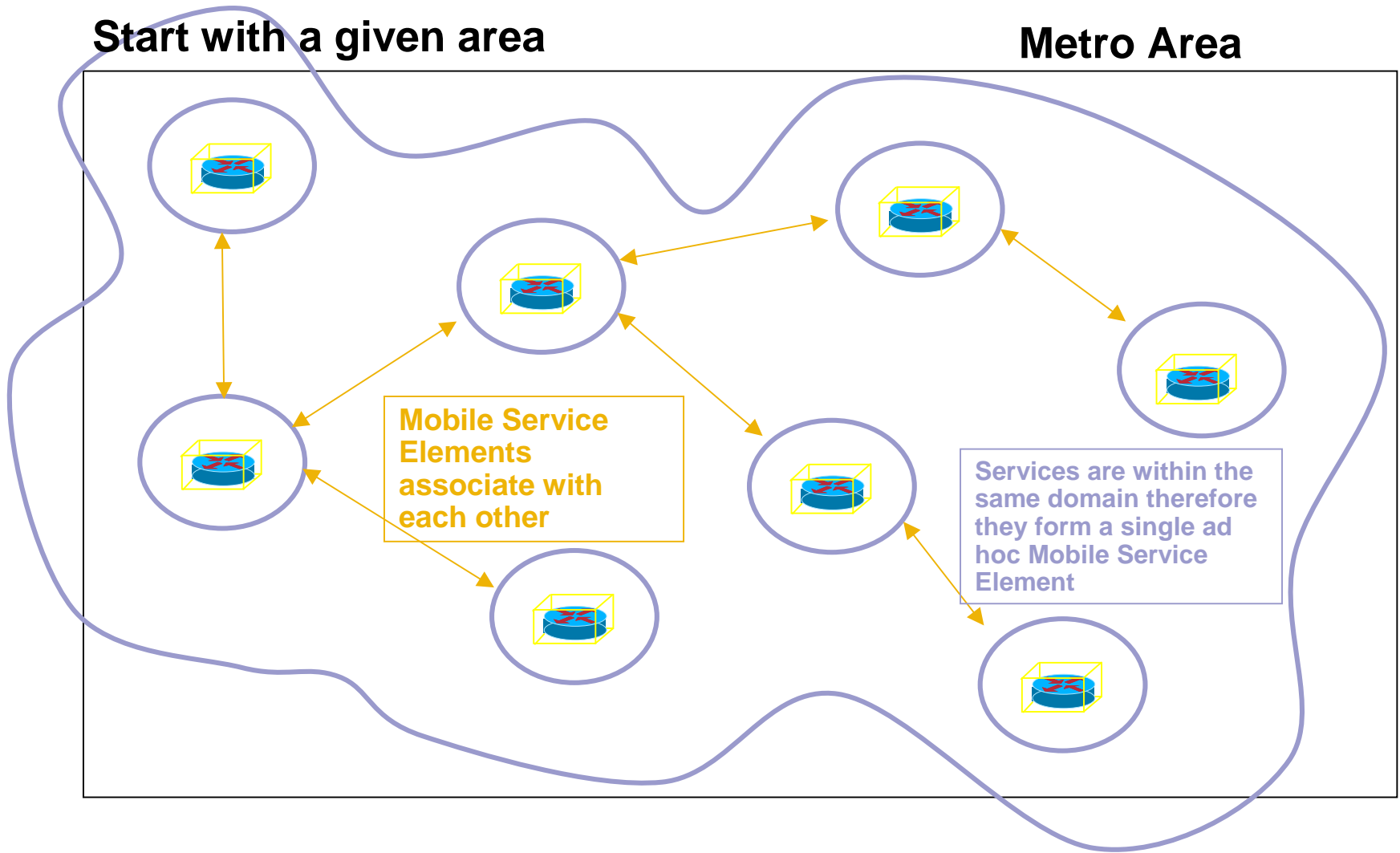


Given that they can reach each other then they should be able to use their standard services such as placing a VoIP call between each other

# Self Forming Service Network

Start with a given area

Metro Area



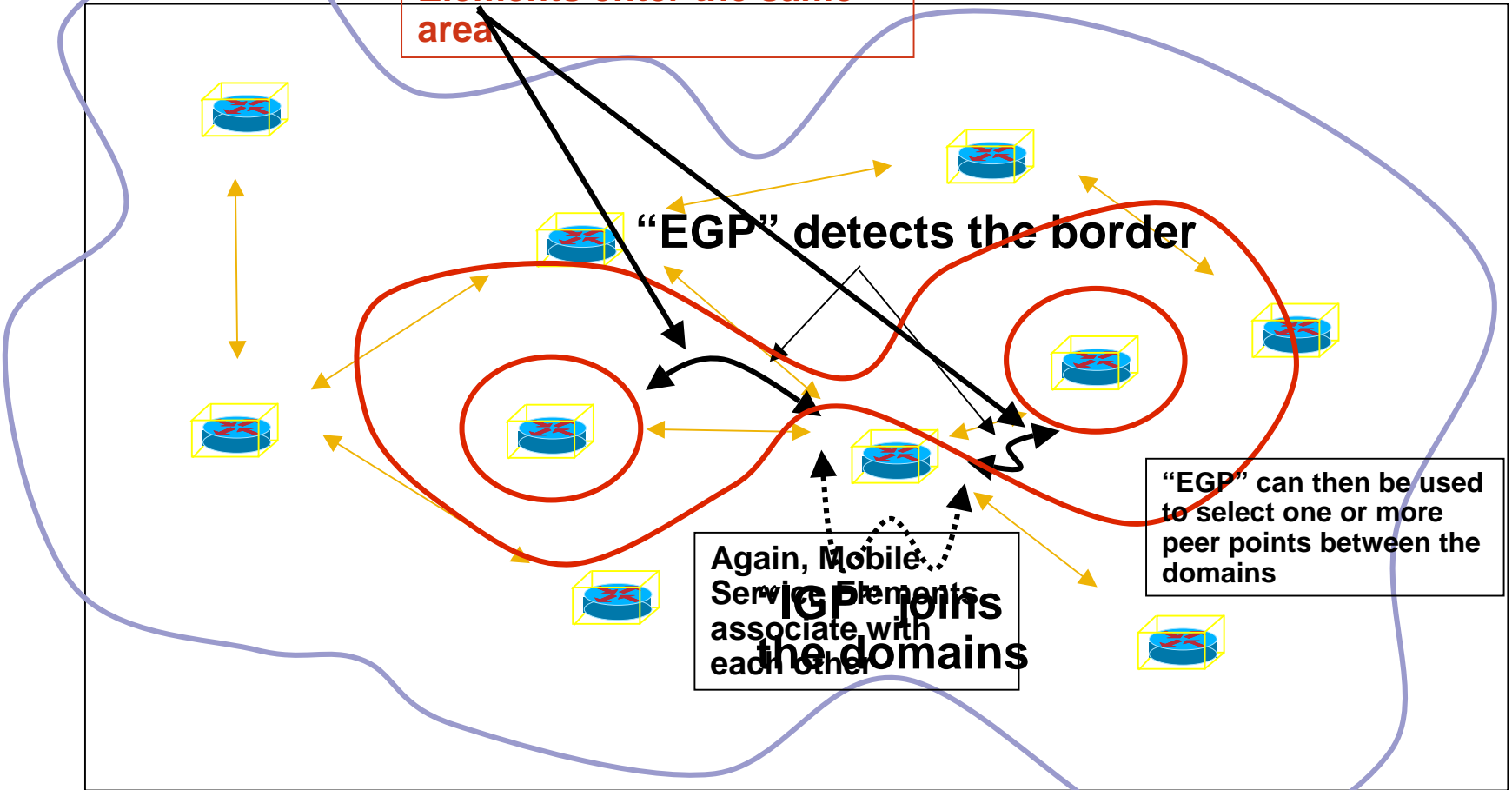


# Self Forming Service Network

The two ad hoc services atoms have now established ad hoc borders

Service borders enter the same area

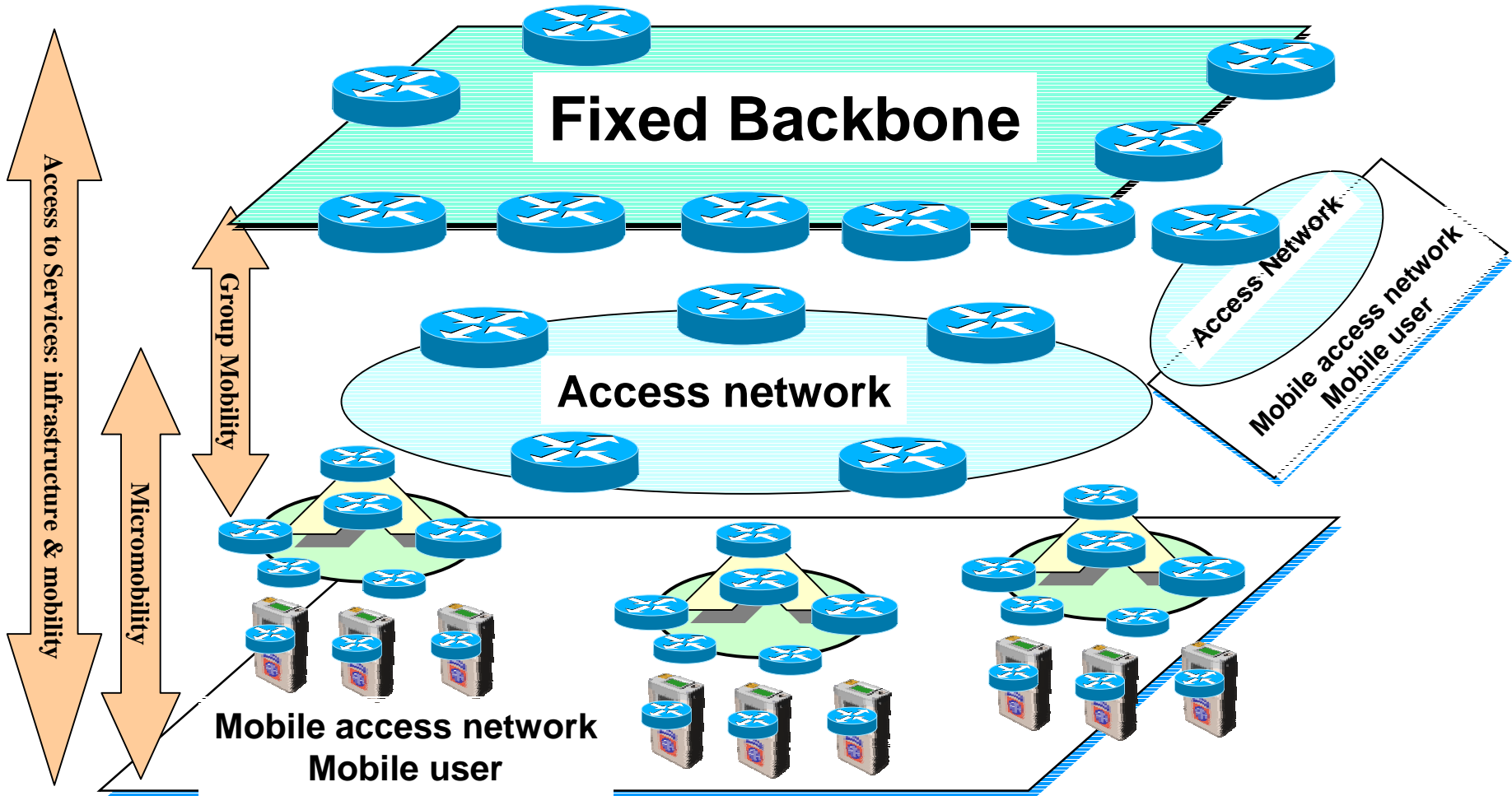
Metro Area



# Some technology



# IP Mobility: problem definition



- Access routers are mobile or fixed

# Ad Hoc mobility

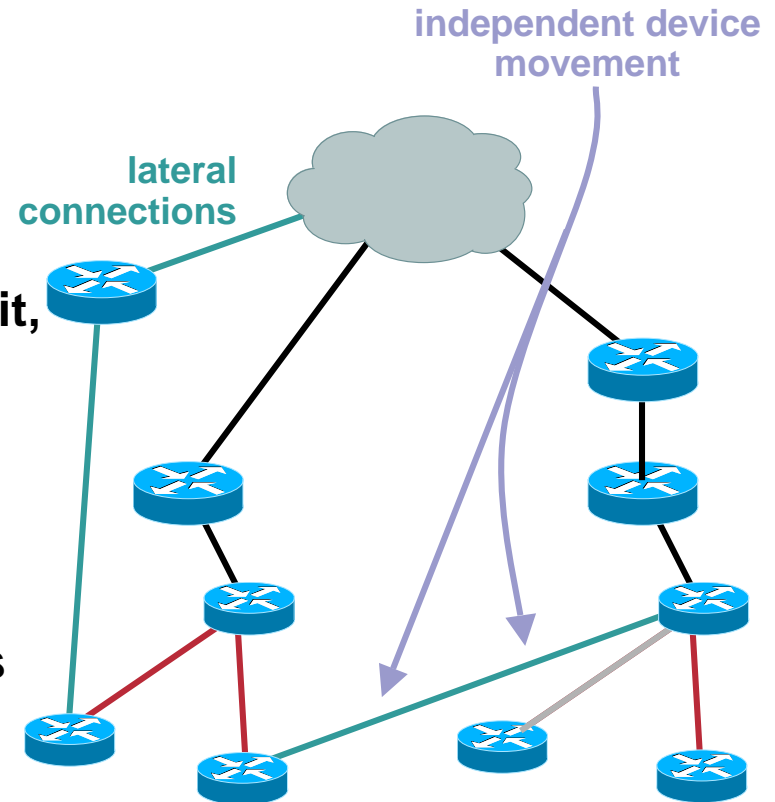
- **Ad Hoc Mobility**

**Hosts move independently**

**If a network is going to move as a unit, hosts attached to it would be numbered in the same IP address space**

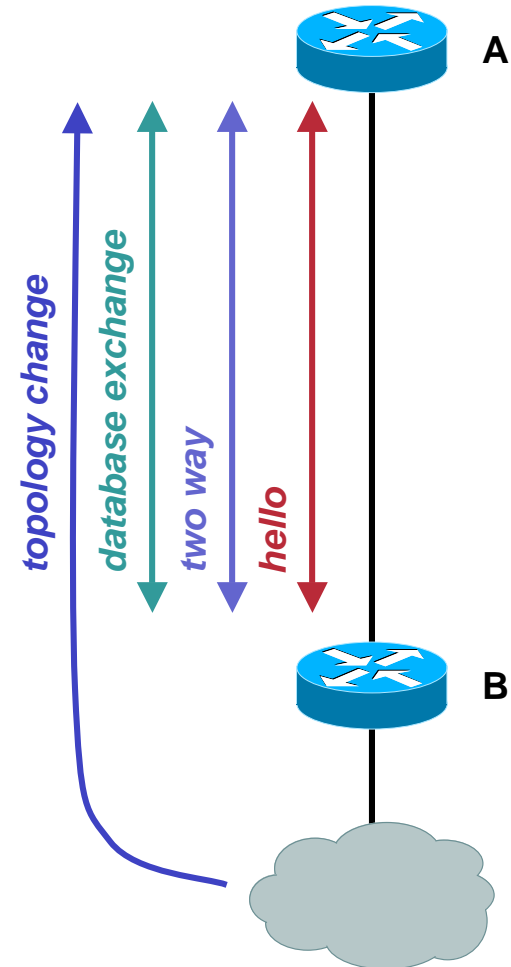
**No “reach back” to any specific network is guaranteed**

**Lateral connections between devices are common**



# OSPFv3 optimization

- Consider normal link state operation:
  - Discover Neighbors
  - Verify Two Way Connectivity
  - Exchange Link State Databases
  - Flood New Information
- Multiprotocol support : IPv4 & IPv6
- Router-radio interface



# Router-Radio Architecture

- Router-radio interface has what amounts to virtual circuits:

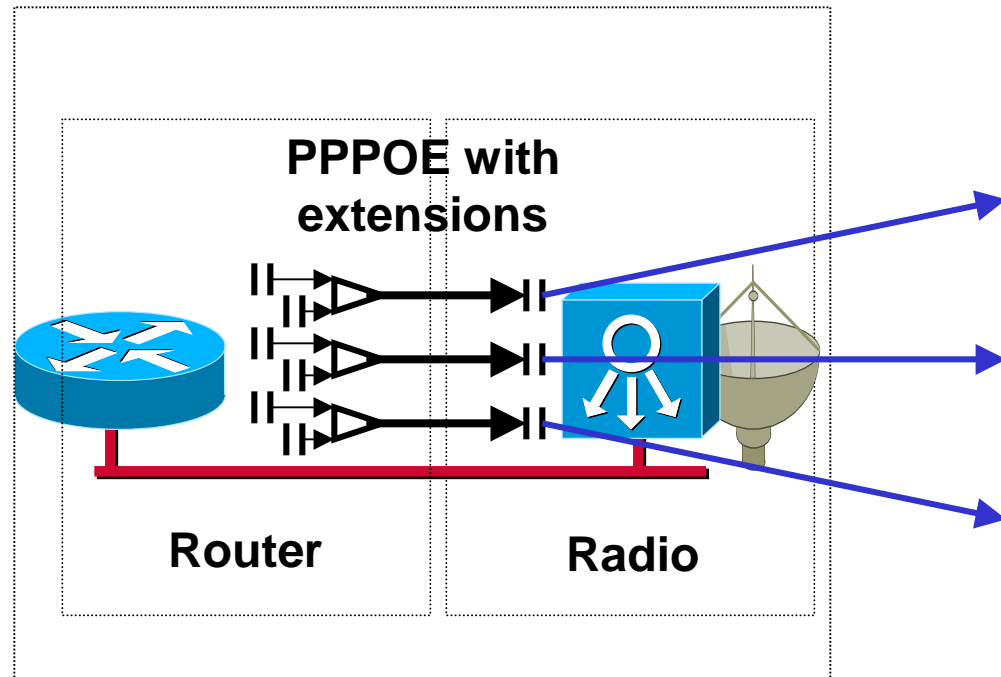
Each routing neighbor has a different data rate, managed by the radio

Therefore each neighbor must have its own windowed protocol, and it must be windowed to control rate

There must be separate QoS data structures per routing neighbor

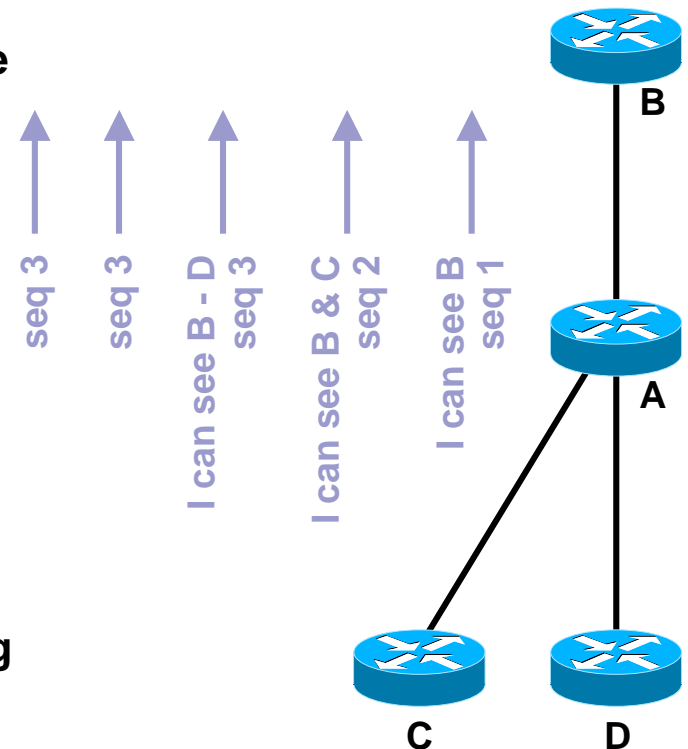
PPPoE sessions are established between the router and the radio – a session for each neighbor

Radio detects and authenticates neighbors, reports neighbor joining or leaving (LOS) to router



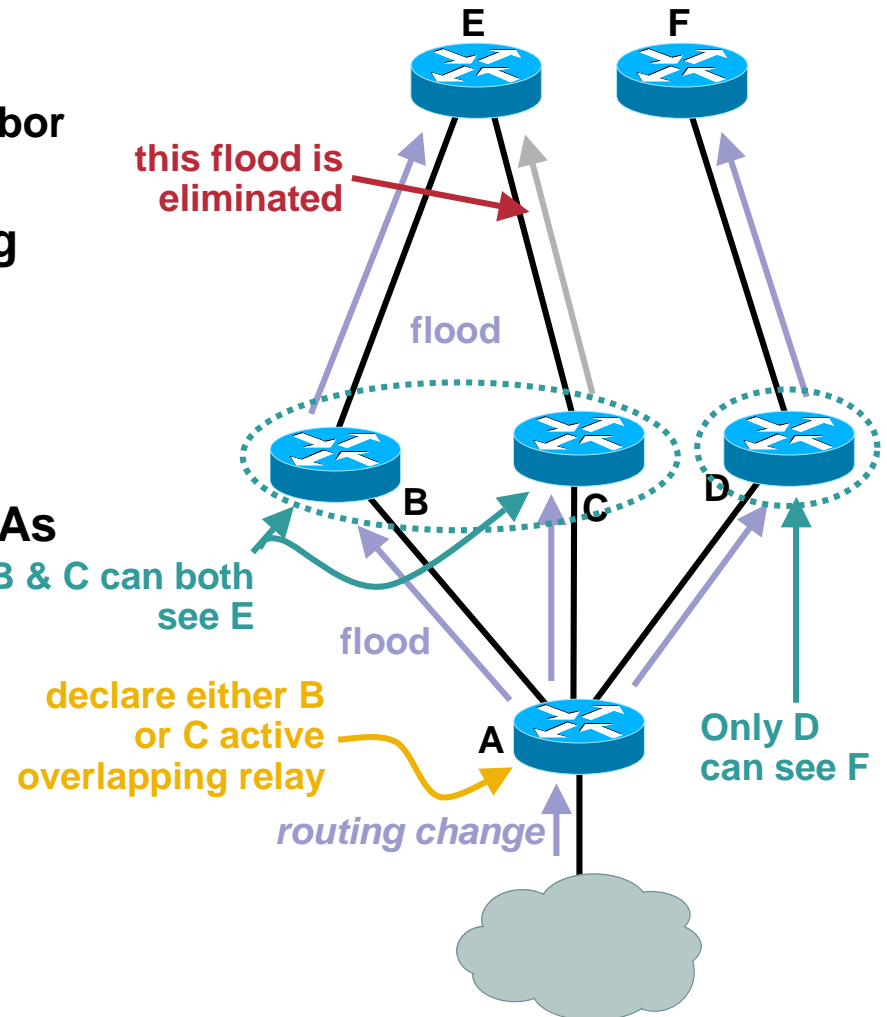
# Incremental Hello: not full neighborhood list

- Reduces the state carried in hellos to the minimum possible, while ensuring two way connectivity
- Receiver can request a state update to synchronize
- Two-way connectivity check
- Incrementally update as neighbor state changes
- Replace the state with a state sequence
  - A small (32 bit) number
  - Indicates “current hello state”
- Each time the sender changes state
  - Include new information
  - Increment the state sequence
- Include information about capabilities (Overlapping Relays, Willingness)



# Optimized Flooding : overlapping relays

- Find common “two hop” neighbors  
Group neighbors based on their neighbor sets
- Calculate minimum set of overlapping relays  
Pick one neighbor from each group of neighbors with the same “two hop” neighbors
- Signal overlapping relays to flood LSAs
- Remaining neighbors do not reflood learned information (they backup the active overlapping relay)





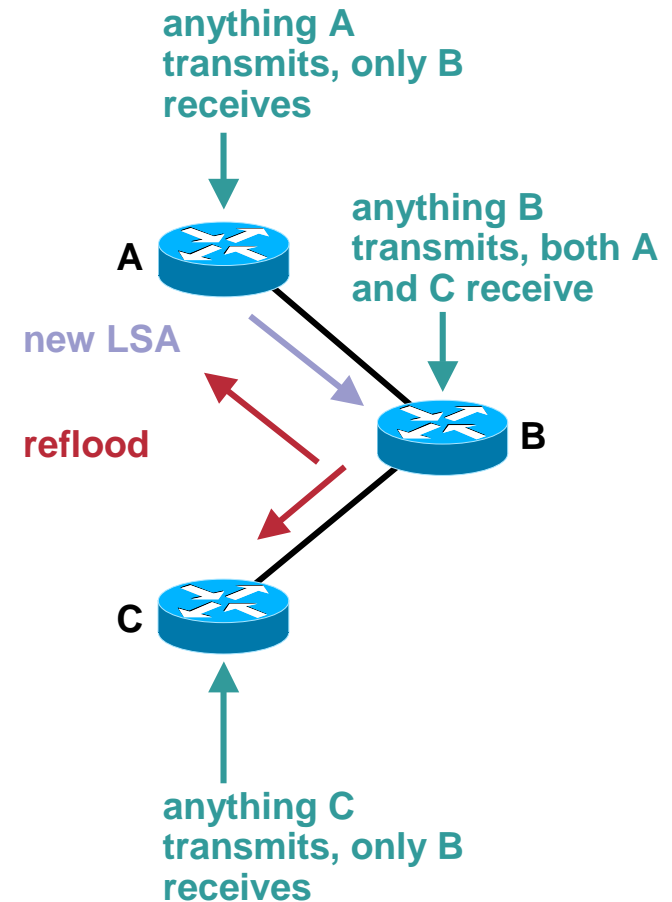
# Intelligent Acknowledgements

- **Why should B acknowledge A's LSA if A is going to hear B's reflood to C?**

If B is reflooding the LSA, A can assume B received it correctly

- **A uses B's reflood to C as an acknowledgement**

Cuts down on traffic on the wire



# Other “ad hoc” systems

- **802.11 ad hoc mode**
- **Proprietary L2 radio systems**
- **MANET family**

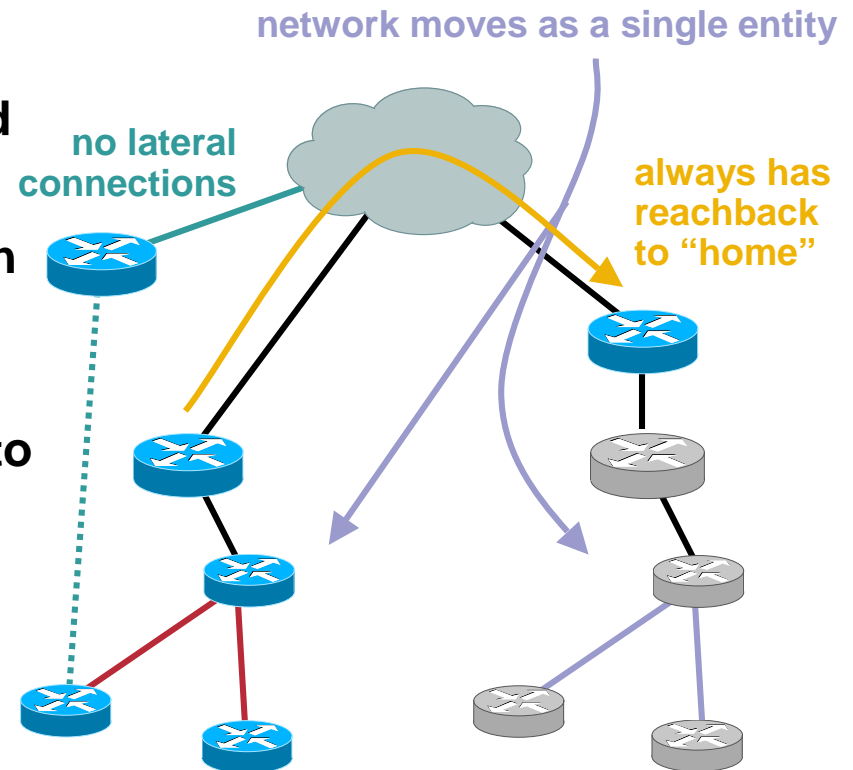
# Device/Network mobility

- **Device/Network Mobility**

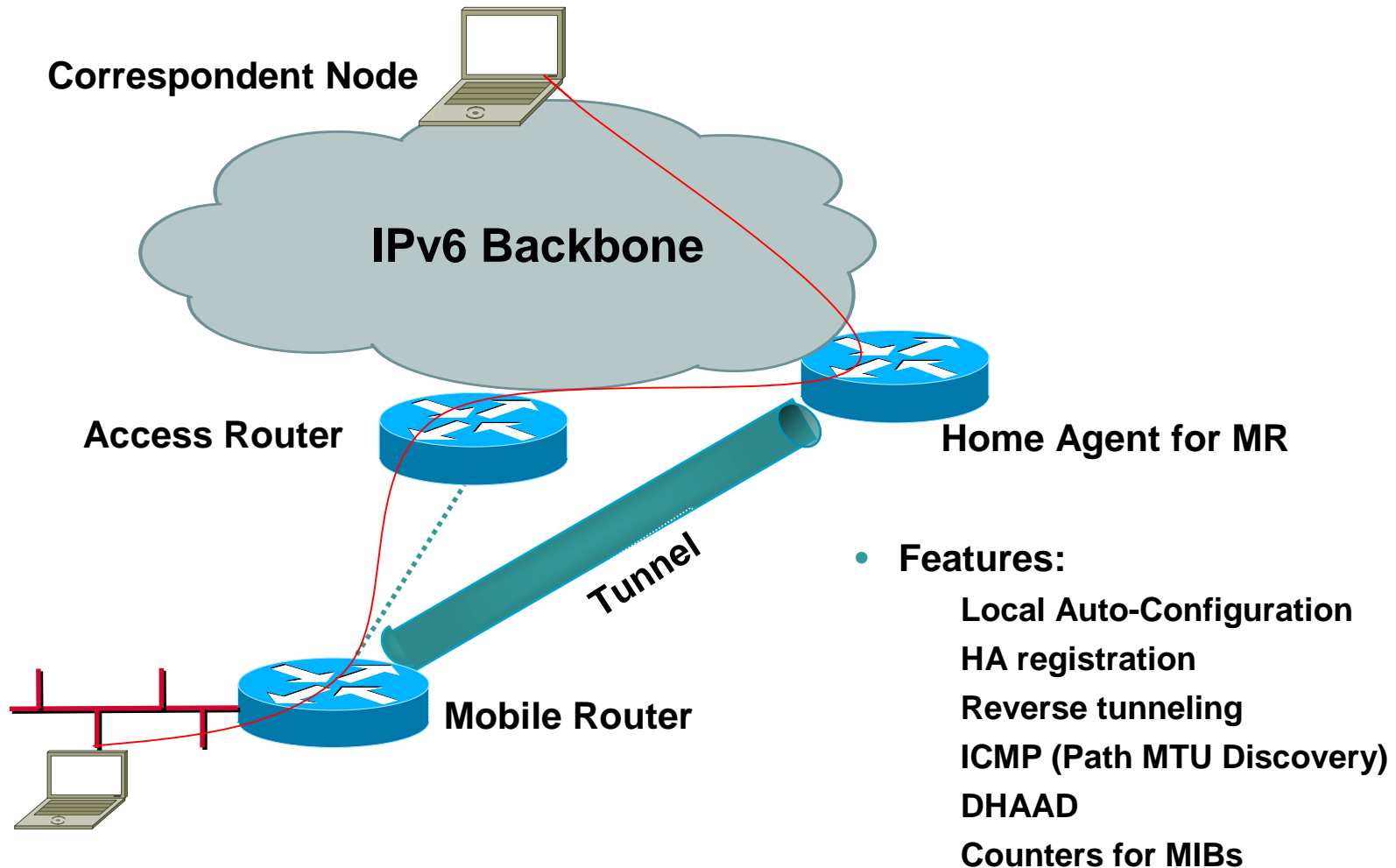
**A host or network (including attached hosts) moves as a single entity**

**The host or network can always reach back to a “home” without worrying about bandwidth utilization, etc.**

**Each host or network connects only to its upstream—no lateral connections**



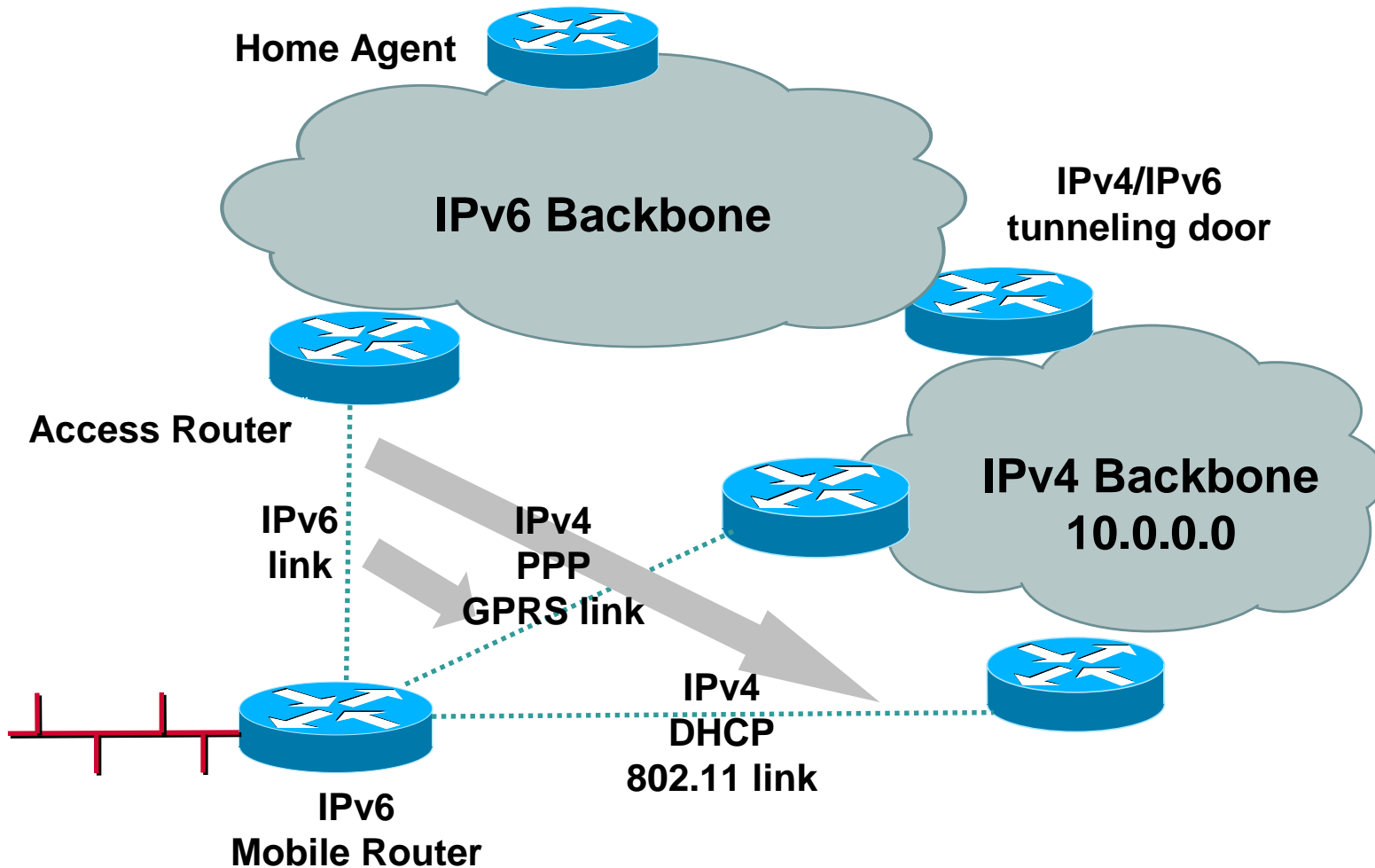
# Mobile Router IPv6: simple scenario



# NEMO Basic: constraints

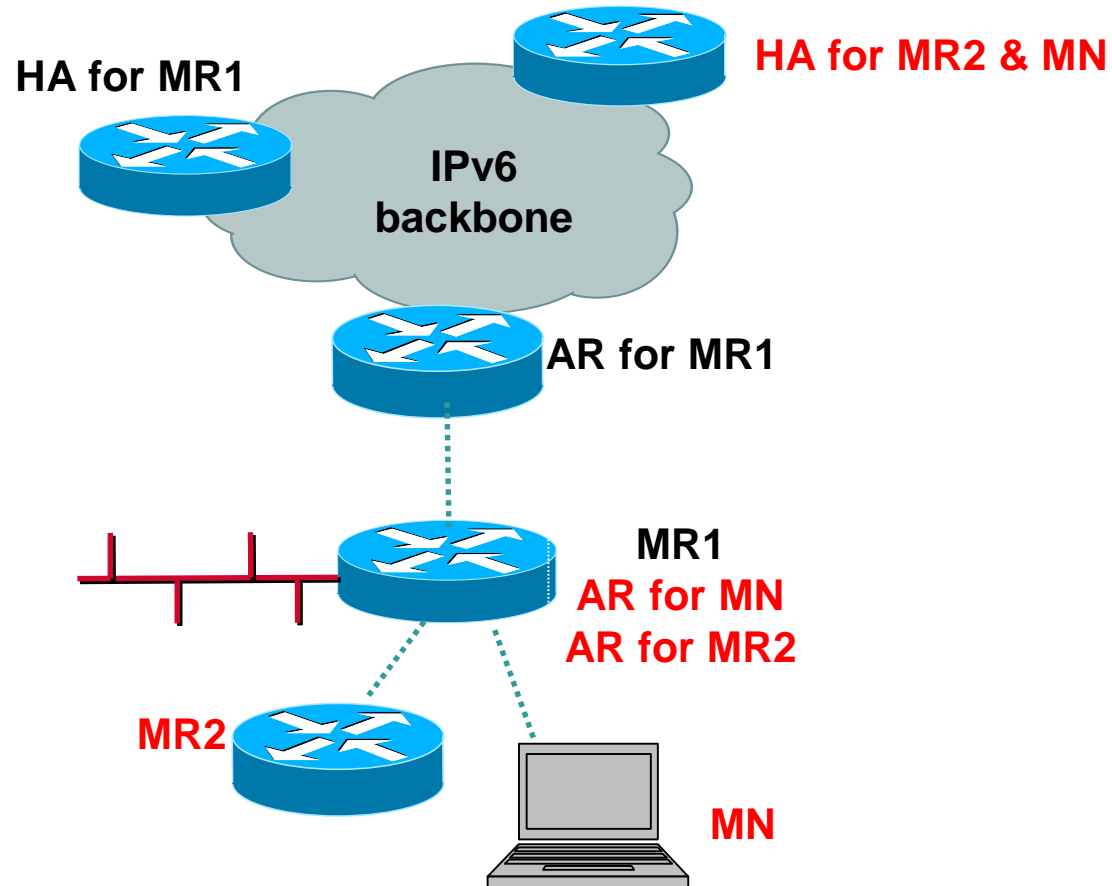
- **Undefined process to select access router**
- **Undefined support for roaming into v4 network**
- **Undefined Route Optimization**
  
- **Intrinsic restrictions**
  - Pinball routing in the infrastructure between the HAs**
  - Security associations and traffic flows**
  - Overhead - Frame size**
  - Bind Update storms**
  - Optimization → Bind Update storms in case of moves (large tables to be stored in MR)**
  - Route Optimization issues**

# Network Mobility

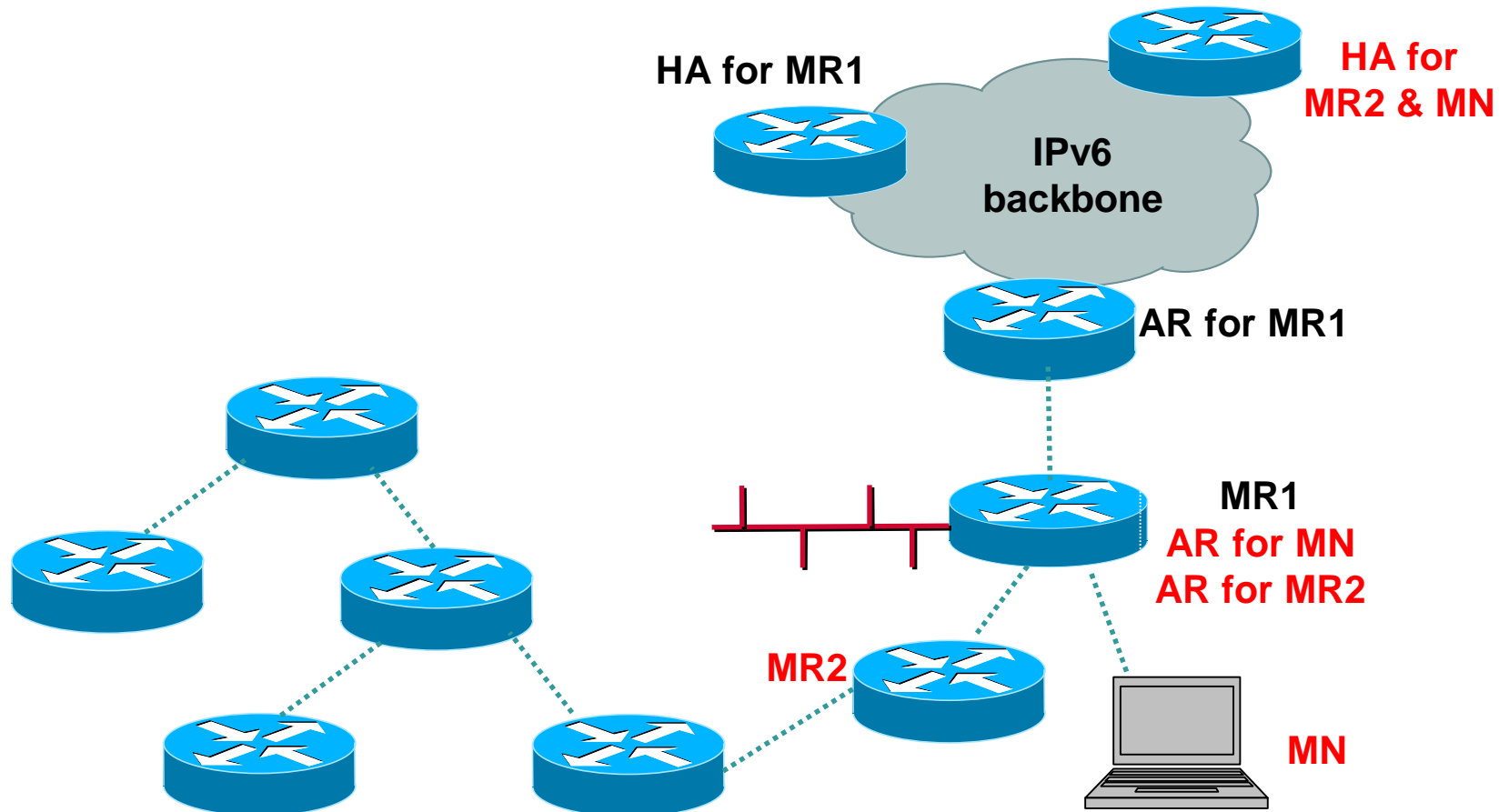


- **IPv4 roaming: need for NAT/PAT for IPv4 and automatic IPv4/IPv6 tunneling**

# Mobile Access Router



# Network Mobility: graph management





# Innovation or adoption call?



# Waves of Innovation

courtesy of V.Bahl (Microsoft Research)

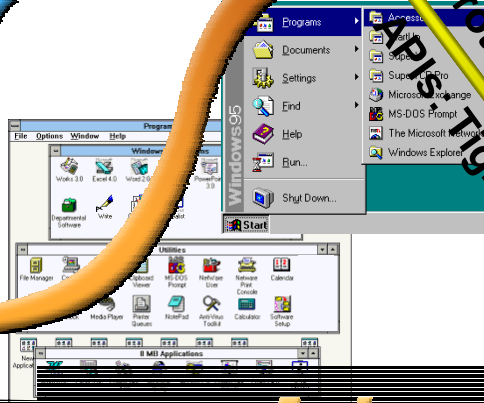
**Development**  
 Hard Engineering → Intellectual Property

- Wi-Fi/Broadband
- Devices
- Speech/Handwriting
- Web Services
- Trusted Computing Hardware
- Rights Management

- XML/SOAP
- HTTP/HTML
- SMTP

- Email Clients
- Web Browsers

- Mouse
- GUI
- LANs



Protocols: Loosely Coupled  
 APIs: Tightly Coupled

- PC Architecture
- DOS

- Spreadsheets
- Word Processors

**Adoption**  
 Intellectual Property → Consumer Benefit

Today

PC  
 Mid 80s



Applications  
 Late 80s-Mid 90s

Internet  
 Mid 90s



Web Apps  
 Mid 00s - ...



# CISCO SYSTEMS

